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M. S. Weinstein
R. J. Hecht
L. A. Mole

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STATISTICAL ANALYSIS OF
OCEAN NOISE (U)

February 20, 1973

Prepared by:

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13. ABSTRACT

(C)A systematic analysis of low frequency ambient noise from a single element of a bottom and suspended array near Barbados was made. The noise statistics are different for bottom and suspended hydrophones as well as for different frequencies on the same hydrophone. For large bandwidth time products (BT) the noise distribution is skewed toward the higher noise levels; but for small BT the noise distribution is normal. Decorrelation times for large BT range from 1/2 to 5 hours.

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The study was conducted under the direction of LCDR T. J. McCloskey, ONR 102-OSC (LRAPP), acting on behalf of Col. D. Russell, ARPA.

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INTRODUCTION

(U)A systematic analysis of low frequency background noise has been undertaken to determine the dependence of noise statistics on processing procedures and environmental factors. The processing procedures of interest include the bandwidth and averaging time. Environmental factors include consideration of the spectral character of the noise and system environment interactions. The presence or absence of surface ship generated line components and the proximity of the surface and bottom interfaces are of particular interest.

(U)Utilizing long term continuous noise samples the measured quantities are the mean noise level, its distribution and standard deviation, and the decorrelation (relaxation) time determined from noise level autocorrelation computations.

(U)The study goals are: (1) To obtain statistical noise data at bandwidths and averaging times appropriate to direct application for predicting surveillance system performance; to compare these results with analytic assumptions made in the absence of experimental data; and, to the extent that they differ, to identify the impact on analytic procedures. (2) To identify any special requirements for data gathering and processing to satisfy this need. (3) To identify any special characteristics of the noise statistics which could be employed to improve surveillance system performance.

(U)The analysis was limited to the above study goals as a necessary initial step in a systematic analysis of the statistics of noise, signal, and signal to noise ratio for specific passive surveillance systems of interest. In our opinion, a systematic approach offers the best opportunity for identification of the sources of fluctuation in signal to noise ratio for different surveillance system concepts.

BACKGROUND

(C) Studies of surveillance systems have demonstrated that performance is dependent upon the detailed system and environmental characteristics. Recognition of the requirements have evolved gradually as experience has been gained with advanced systems.

(C) Early evaluation of acoustic system performance led to the development of the sonar equation. This concept is relatively simple. Average noise levels, target characteristics, and system capabilities, are summed to obtain a sonar Figure of Merit (FOM). The range to the target for which the FOM is equal to the propagation loss is the range for single look 50% detection probability. If none of the parameters fluctuate with time, 100% detection probability is achieved at shorter ranges, with zero probability at longer ranges. Because of fluctuations this is modified to reduce the detection probability at shorter ranges and to increase the probability at longer ranges, shown conceptually in Figure (1). The exact shape of the probability curve depends upon the functional dependence of average propagation loss with range, and the fluctuation statistics. At the current time the fluctuations in signal to noise are treated by assuming a log normal distribution and estimating the standard deviation to be of the order of 7 or 8 db.

(C) The 50% single look detection range, and the single look detection probability curve, are very useful criteria for determining the effectiveness of a surveillance system. They can be used to compare the performance of different systems in the same environment; and the same system in different environments. However, they are not sufficient to fully quantify system performance.

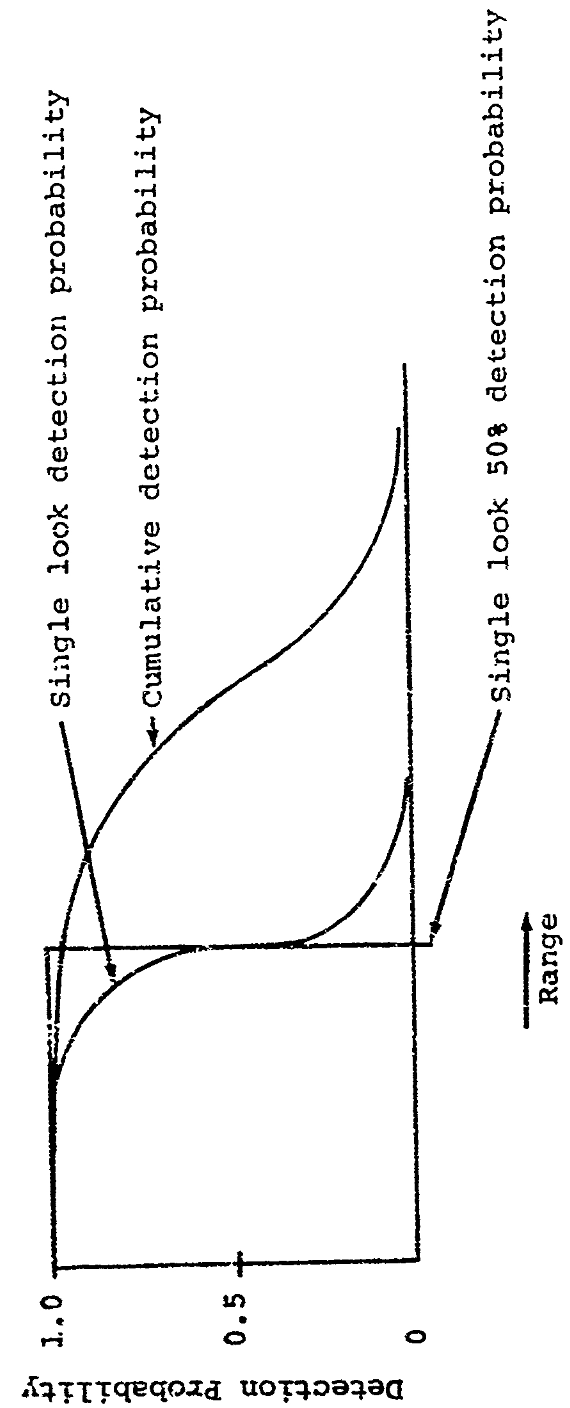

Figure (1)
Illustration of detection probability

(C)A common problem is to determine the probability that a target is detected at least once if it remains within a pre-set area for a predetermined period of time. Alternatively one can ask how many system installations are necessary to achieve a predetermined detection probability. To resolve these problems the cumulative detection probability is needed. This is obtained by considering the target track and speed, and determining the probability that the target will be detected at least once during a pre-set time period. A cumulative detection probability of 95% in a 24 hour period is frequently used as a goal.

(C)The fluctuation in signal to noise ratio has to be known to determine the single look detection probability curve. If the dependence of the fluctuation on time is also known, the cumulative detection probability can also be computed. In current practice the time dependence is usually considered to be a "decorrelation" or "relaxation" time of the order of 1-1/2 hours. This is equivalent to stating that the auto-correlation function of the fluctuation is reduced to 1/e in 1-1/2 hours. This determines the change in the signal to noise ratio which can occur between "independent" look intervals. The final cumulative detection probability curve is illustrated in Figure (1).

(C)While this concept has considerable merit its application raises serious questions. The assumption of a log normal distribution and a decorrelation time leads to a non-zero probability of detection at any range, no matter how long, if the target loiters for a long enough period of time. To cope with this, it has been suggested that the distribution be truncated at one or two sigmas to remove the tails of the distribution. Truncation can be challenged as arbitrary, leading to an artificial range beyond which detections can not

be made. Alternate suggestions have included skewed statistics with and without truncation. The difficulty does not lie with the general concepts for computing cumulative detection probability, but the paucity of experimental data which describe the necessary statistics. In the absence of hard data the assumption of statistical forms readily amenable to analytic procedures is quite logical.

(C)The statistics of fluctuation in the signal to noise ratio consists of the appropriate sum of the statistics for fluctuation in propagation loss, background noise, and target level. It has been suggested that under some conditions fluctuation in propagation loss and background noise may have a small positive correlation, but, basically we can consider the three sources of fluctuation as independent. To understand the total fluctuation it behooves us to understand the individual fluctuations and the factors which influence them.

(C)Fluctuations in propagation loss are readily defined for the case of a fixed source and fixed receiver, and depends entirely upon temporal changes in the environment. When the source is permitted to move the fluctuation must be understood to represent a distribution about a range dependent propagation loss curve. This adds considerable complexity since it requires the adoption of an "average" propagation loss curve along the track of the source. The deviation of data points from this "average" curve depends upon the amount of detail included in the "average" curve, as well as the effect of the temporal fluctuations, so that a certain amount of subjectivity enters into the problem. Since this report is devoted to fluctuation in noise, no further comments will be made on fluctuation in propagation loss or target level.

(C)By contrast, fluctuations in noise at a fixed receiver are more readily defined. Although spatial factors are present, notably the movement of surface ships which control the noise

level at low frequencies, these factors are reflected as temporal fluctuations at the receiver, and can be so treated. Thus, a systematic experimental investigation of fluctuations in noise appears to be an appropriate beginning for understanding the total fluctuation in signal to noise ratio.

(C) In performing a systematic experimental investigation it is desirable to set forth a number of goals. These are presented here as a set of parameters upon which the noise statistics may depend. In each case a speculative theoretical basis is set forth for the dependency, to be verified or denied by the experimental results.

1. Dependence of Bandwidth

   (C) Measured noise levels are generally reduced to spectral levels at the center of the band by applying a correction factor of 10 log BW. If the spectral levels are reasonably flat over the bandwidth, and strong line components are not present, we expect the results to be essentially invariant for progressively narrower measurement bands. However, if strong line components are present, reduced spectrum levels may change considerably as the bandwidth narrows, depending upon whether the line components are included or rejected.

2. Dependence on Averaging Time

   (C) Existing and conceptual passive surveillance systems utilize averaging times of minutes to tens of minutes. Data gathering programs have utilized averaging times ranging from seconds to hours. Assuming that the bandwidth time constant product is always greater than one, any dependence of the noise statistics on averaging time will be related to the decorrelation time.

3. Proximity to Interfaces

(C)Noise statistics may be dependent on the proximity of the sensor to the surface or bottom interfaces. The total noise field consists of the summation of signals received from a large number of surface ships. The multipath propagation from each ship can be considered to consist of a number of paired propagation paths; one member of the pair having an additional surface or bottom reflection at the end of the propagation path. For a sensor close to an interface the contributing reflecting area should generally be smaller than for a sensor distant for an interface. Phase variations may therefore be more rapid resulting in larger fluctuations. If such an effect is found, it would imply that fluctuations in propagation loss will also be higher for a hydrophone near an interface.

4. Array Aperature

(C)Most noise measurements are made with omnidirectional hydrophones; yet, horizontally directional arrays are a powerful tool in surveillance. It is well known that low frequency noise fields are generally anisentropic, so that a signal to noise improvement of 10 log n, where n is the number of hydrophones, is usually not correct. As the beam width narrows the number of surface ships which contribute significantly to the total noise field is progressively reduced. For a small number of contributing surface ships spatial redistribution as a function of time should lead to larger fluctuations. An additional factor is the variation of coherence across the array aperature for the signal from each ship. This may be significantly more important for bottom arrays than for suspended arrays.

(C) We do not address all of these questions in this report. Specifically, data for a single bottom and a single suspended hydrophone has been used. The effect of array aperature was therefore not considered. Additionally, strong line components were generally not present over the bandwidths studied; at least as viewed through an omni-directional hydrophone. However, simultaneous recordings of some array beams are available for further study and comparison with the results reported herein.

RESULTS OF THE ANALYSIS

General

(U)There are two general characteristics of the noise which should be borne in mind while reviewing the analysis results.

(U)1. The variation in noise level over the entire period was moderate. Variation of the broadband noise level was sufficiently small to permit recording of each hydrophone on a single channel without gain changes for the entire 9¼ day sample. Four hour averages of the processed bandwidths had a total range of about 10 db.

(U)2. As seen through omni-directional hydrophones strong line components were generally not observed in the processing bandwidths. This was readily apparent from oscillograph viewing of the 1/3 octave filter outputs, and was spot checked by detailed analysis as shown in Figure (A4). Since there is no significant difference in the levels between the different filter bandwidths the probability of line components is very small. Continuous narrow band analysis over the 1/3 octave bands was not employed, so that the occasional presence of line components can not be entirely precluded.

Data Sample

(C)A 9¼ day data sample was obtained for a bottom hydrophone near Barbados, BWI at a depth of approximately 3,000 feet, and a suspended hydrophone in the MILS Array at a depth of 3,100 feet in approximately 1,500 fathoms of water. The recordings were obtained by NUSC, New London, as part of the Translant II exercise.

(C)The data was processed at center frequencies of 100 Hz and 50 Hz with bandwidths of 1/3 octave, 1/10 octave, 1.0 Hz and 0.2 Hz. Spectrum levels were determined by energy integration over predetermined time intervals, converted to decibel levels, and corrected for bandwidth and integration time. Averaging times of 10 seconds, 1 minute, 10 minutes, 1 hour and 4 hours, were employed.

(U)The results are presented in the form of average levels, standard deviations, histograms, autocorrelograms and decorrelation times of the noise levels.

(U)Additional details covering processing procedures are given in the Appendix.

Average Levels and Standard Deviation

(U)Tables (A1) to (A4) show the mean noise level and standard deviation for four bandwidths with 10 second to 10 minute averaging times for the two hydrophones at center frequencies of 50 and 100 Hz for the entire 9¼ day sample. The mean noise levels are essentially independent of bandwidth and averaging time except for the 0.2 Hz bandwidth utilizing 10 seconds averaging time, where it is about 1 db lower. The insensitivity of the mean value to bandwidth and averaging time is consistent with the observation that background line components were not observed. The standard deviation, σ, is also stable but tends to increase with decreasing bandwidth time constant. For the 0.2 Hz bandwidth utilizing 10 second averaging time, it is significantly higher, increasing for all data sets by about 1.5 db. The results at 50 Hz for the suspended hydrophone, shown in Figure (2), derived from Table (A3), clearly shows the trend towards increasing standard deviation as the product of the bandwidth and averaging time decreases.

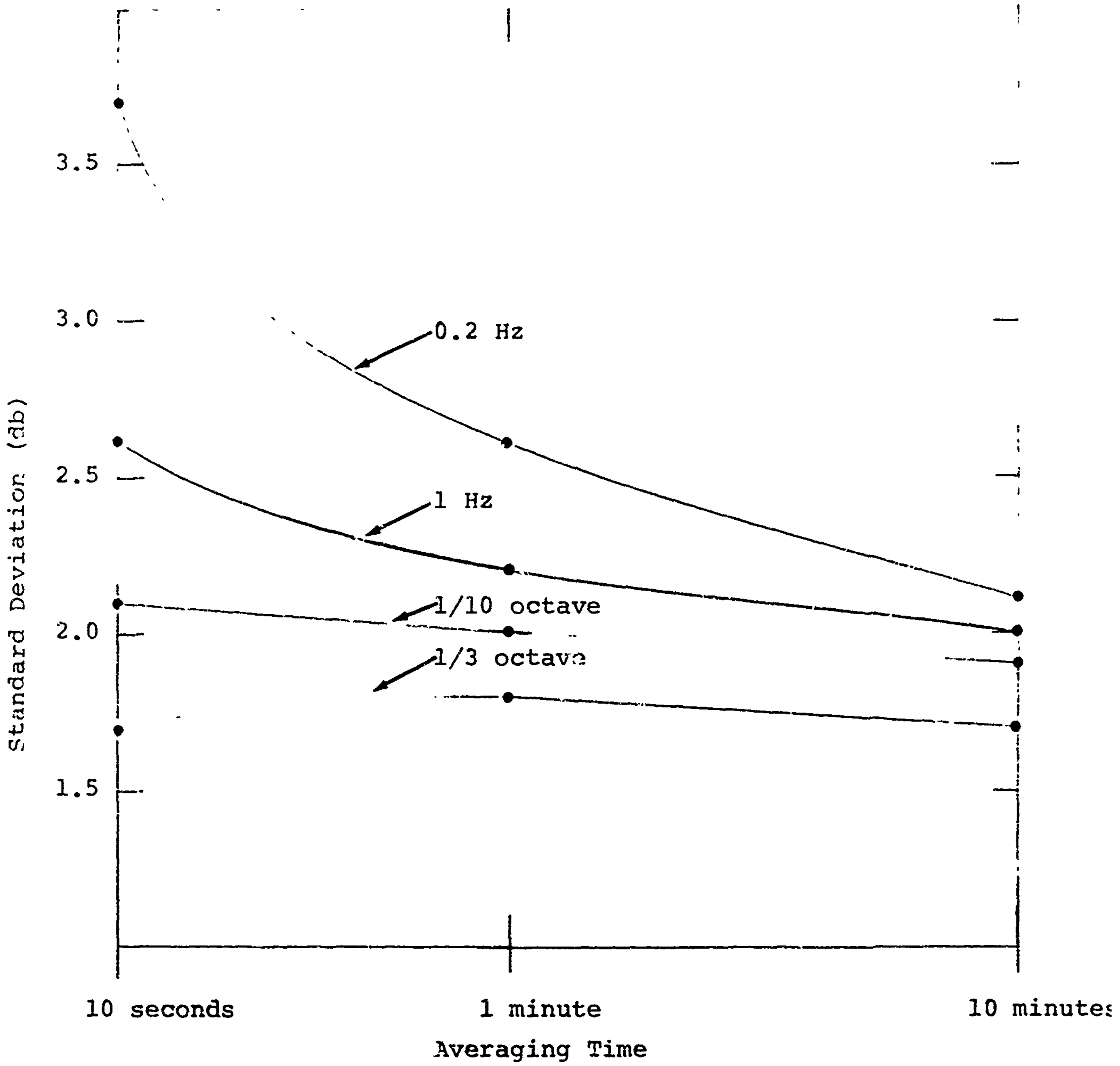

Figure (2)

Standard deviations for the 4 bandwidths as a function of averaging time for the bottom hydrophone; center frequency 50 Hz; sample length 9¼ days.

(U) The standard deviation for the suspended hydrophone is generally lower than for the bottom hydrophone. It is about 0.8 db at the 100 Hz center frequency for all bandwidths and averaging times, except 0.2 Hz at 10 seconds for which the difference is reduced to 0.3 db. For the 50 Hz center frequency the standard deviation is essentially identical for both hydrophones for all bandwidths except for the 1/3 octave band for which it is about 0.4 db lower for the suspended hydrophone.

Distributions

(U) Figures (A5) to (A51) are useful for investigating how the mean values and standard deviations vary with time during the 9½ day sample.

(U) Figures (A5) to (A10) show the cumulative mean values and standard deviation for the bottom hydrophone at 100 Hz. These results indicate that a 24 hour sampling interval may be sufficient to stabilize these parameters. However, the time series plots for 4 hour and 24 hour mean levels shown in Figures (A11) to (A34) for both hydrophones and center frequencies suggest that this is contingent upon the sample starting time and that at least 48 hours of data are necessary to stabilize these parameters. A typical comparison of 0.2 Hz data is shown in Figure (3).

(U) If the 100 Hz and 50 Hz curves for mean levels are overlaid for each hydrophone the positions of positive level excursions are reasonably coincident with a single pronounced exception. There is a positive excursion at about 4½ days at 50 Hz, which is not present in the 100 Hz data. This comparison is shown in Figure (4). It is also apparent that the data spread and curve "roughness" is greater for the bottom hydrophone than for the suspended hydrophone.

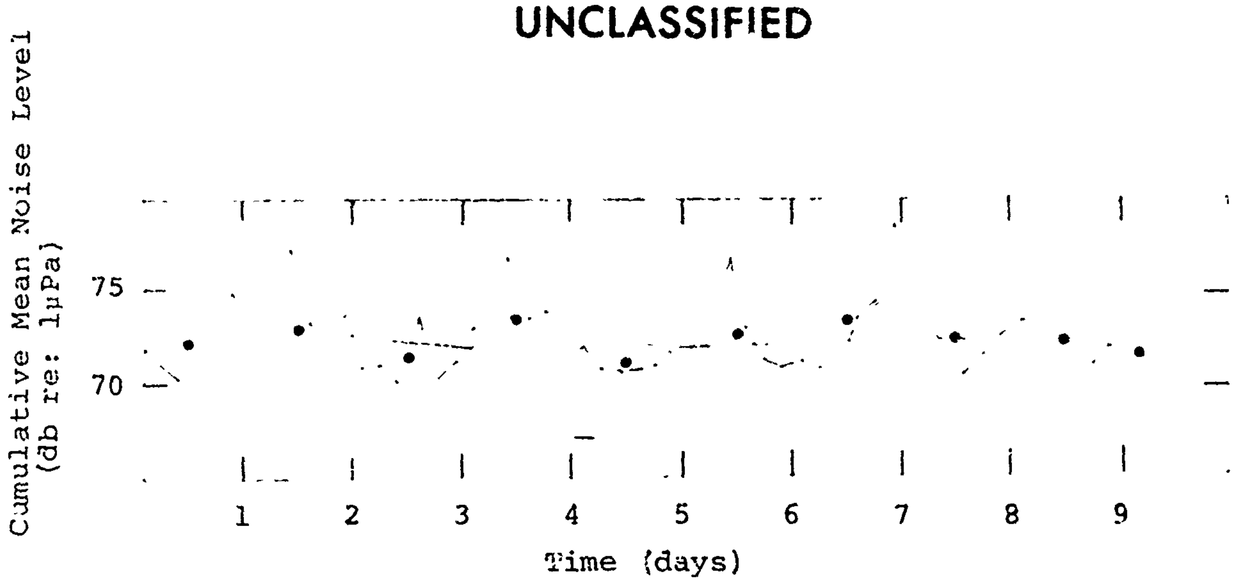

Figure (3)

Comparison of cumulative mean level and mean level for the bottom hydrophone; center frequency 100 Hz; 0.2 Hz bandwidth; 10 minute averaging time.

— = 4 hour
• = 24 hour

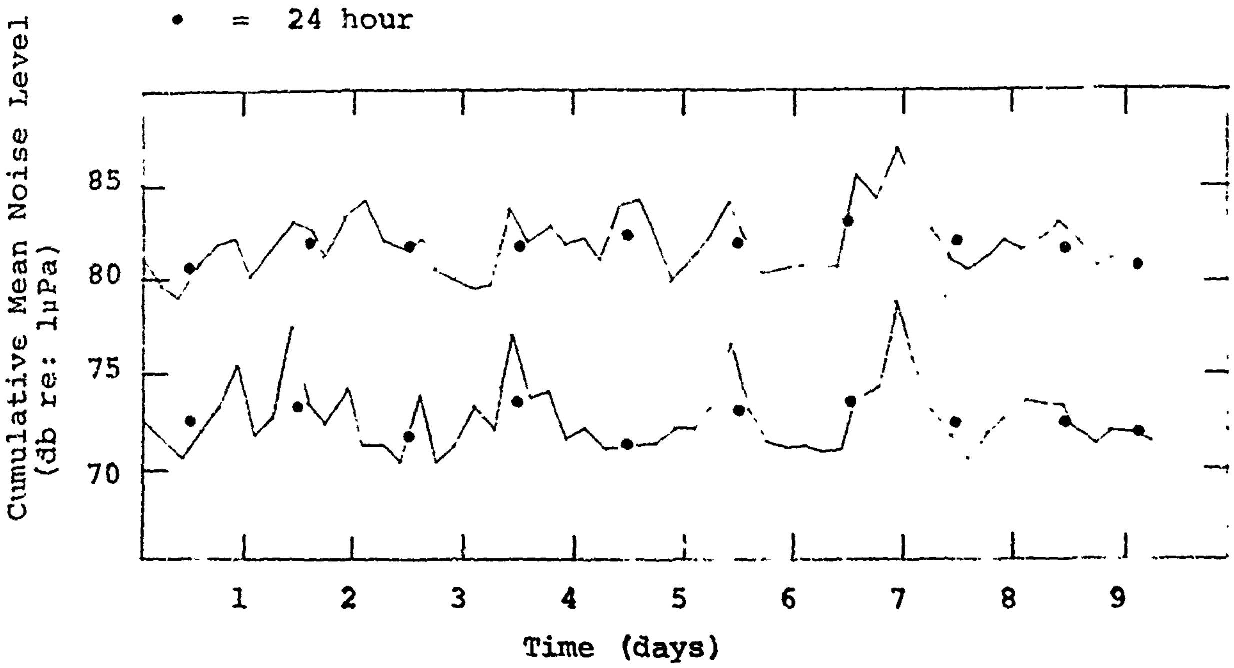

Figure (4)

Comparison of mean levels for the 50 and 100 Hz center frequency, 0.2 Hz bandwidth; bottom hydrophone; 10 minute averaging time.

— = 4 hour
• = 24 hour

(U)The standard deviations, Figures (A23) to (A34), can be qualitatively described as having a base value with occasional excursions to higher values. The histograms for the standard deviation, Figures (A35) to (A46) provides quantitative data. The most probable value of the standard deviation for a 4 hour interval is consistently at the low end of the distribution.

(U)The time of occurrence of large excursions in the standard deviation appears to be weakly correlated with increases in the mean noise level. A typical comparison is shown in Figure (5). Point plots of the standard deviation as a function of mean noise level are shown for a few cases in Figures (A47) to (A51), and show a definite trend towards higher standard deviations as the mean noise level increases.

(U)Histograms of the noise distribution for the entire 9¼ day sample are shown in Figures (A52) to (A76). In general, the distribution is normal for the 0.2 Hz bandwidth and 10 second averaging time, and becomes progressively skewed towards high noise levels as the bandwidth time constant increases. This effect is clearly illustrated in Figure (6) for the bottom hydrophone at a center frequency of 100 Hz and the 0.2 Hz bandwidth. For the 1/3 octave bandwidth the distributions are essentially independent of averaging time and comparable to the results for the 0.2 Hz bandwidth and 10 minute averaging.

(U)The shift from a normal to a skewed distribution is most pronounced for the bottom hydrophone at 100 Hz and least pronounced for the suspended hydrophone at 50 Hz. At both frequencies the distribution is more normal for the suspended hydrophone.

(U)Cumulative distributions plotted on probability paper are shown in Figures (A77) to (A84). A straight line represents a normal distribution. All of these curves indicate some degree of skewness. The deviation from a straight line occurs in the vicinity of 85 to 90% cumulative

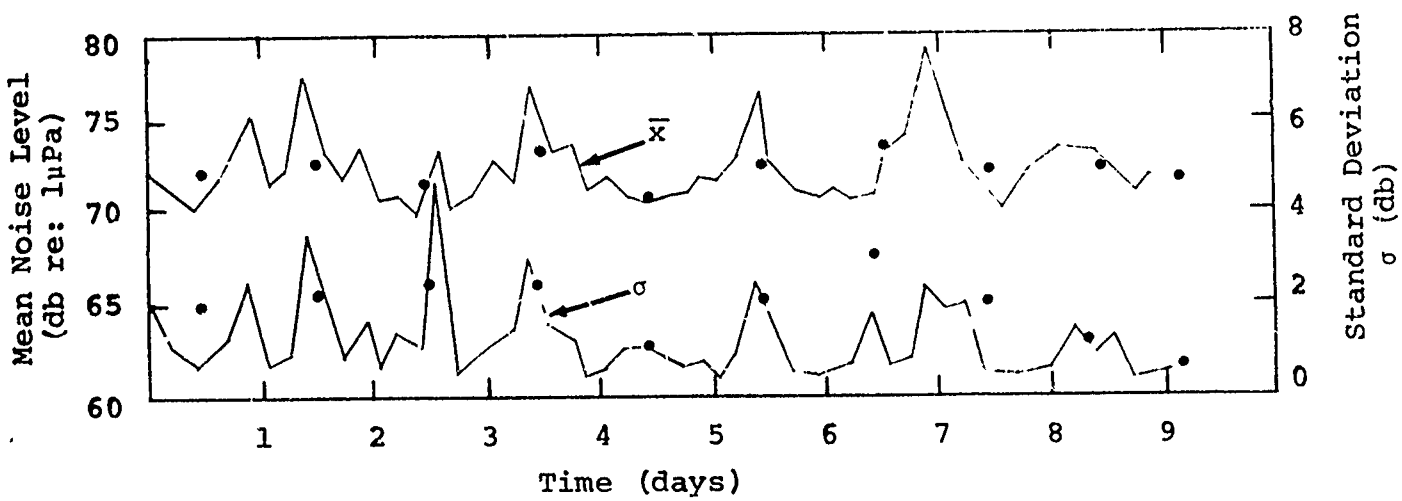

Figure (5)

Comparison of mean noise levels ($\overline{x}$) and their standard deviations (σ) for the bottom hydrophone; 0.2 Hz bandwidth; center frequency 100 Hz.

Legend: 4 hour values. 24 hour values.

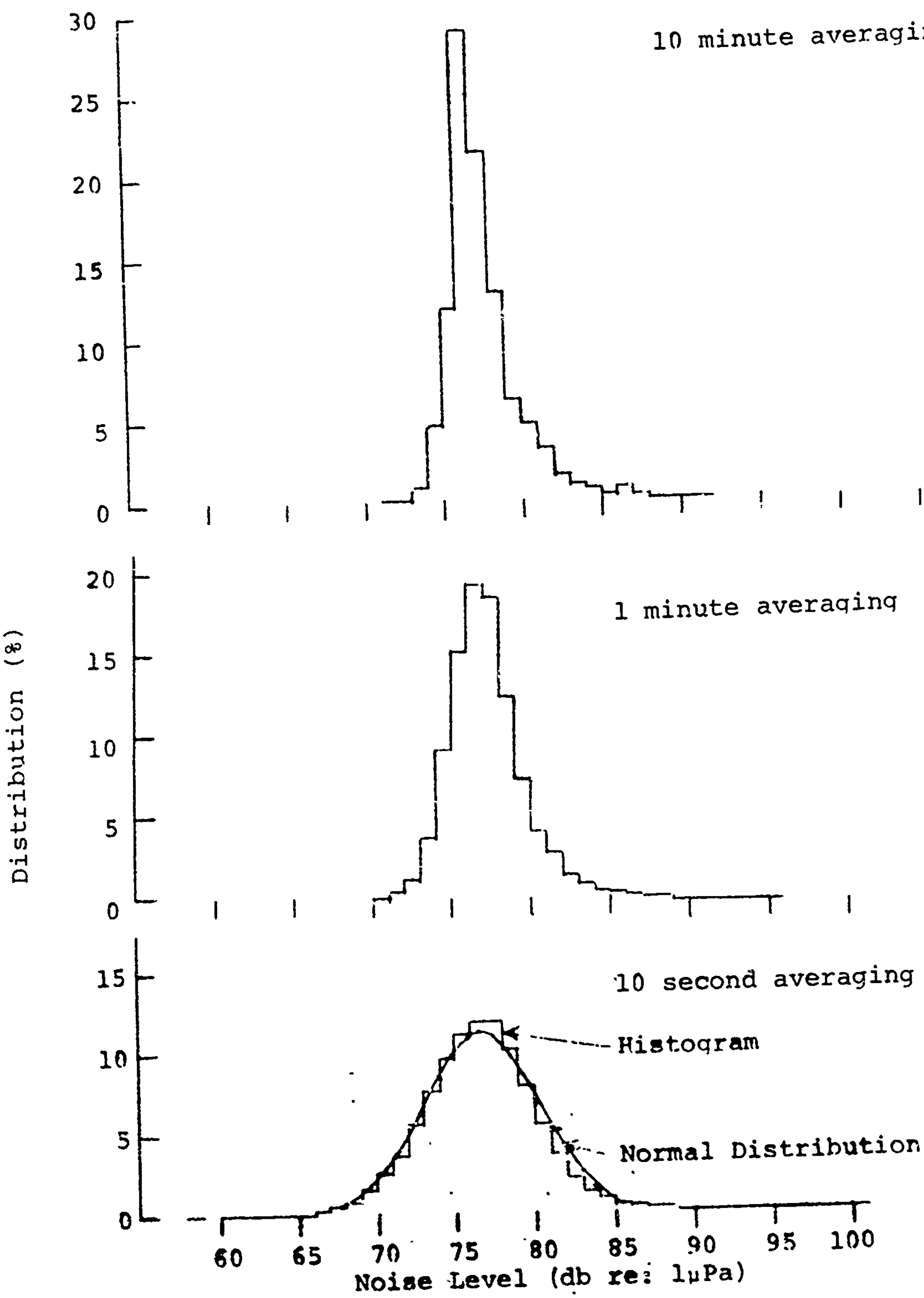

Figure (6)

Noise distribution for indicated averaging times. Bottom hydrophone; center frequency, 100 Hz; bandwidth 0.2 Hz; sample length 9¼ days.

distribution for the bottom hydrophone at 100 Hz with 10 seconds of averaging time. For other conditions the break point occurs at higher distribution levels and the distributions appear to be closer to normal.

(U)Figures (A85) to (A102) show comparative 24 hour distributions for 50 and 100 Hz, for both hydrophones, with a bandwidth of 0.2 Hz and 10 minutes of averaging time. Most of the 24 hour histograms are skewed towards high noise levels, but there are a few cases which are close to normal or slightly skewed to low noise levels. Figure (A98) which shows the 50 and 100 Hz results for day 5 on the bottom hydrophone, is of particular interest. The 100 Hz distribution is very tight with some indication of skewing to low noise levels. The 50 Hz distribution is broad and skewed to high noise levels. As previously noted, on day 5 there is a peak in the 50 Hz mean level vs time curve which is absent from the 100 Hz data. The pronounced difference in the histograms is probably related to this factor.

Autocorrelograms and Decorrelation Times

(U)Figures (A103) to (A114) show typical noise level autocorrelograms. As can be seen, they are well behaved. The time series data and the autocorrelograms were used to determine if there was any pronounced cyclical variation in the data. None was found, although the scalloping in the lower curves of Figures (A103), (A105) and (A107) may be related to tides. Figures (A112) to (A114) show a comparison of 24 hour autocorrelograms for 1 minute and 10 minute averaging. For 1 minute averaging the autocorrelation coefficient shows a pronounced drop within a delay time of a few minutes. This is not indicated in the 10 minute data, and the two results are quite similar after about 100 minutes. These results suggest that there are at least two different phenomena contributing to the fluctuations. One has a

decorrelation time of the order of a minute, the second of the order of tens of minutes or greater. When 10 minutes of averaging time is employed the more rapid fluctuations are averaged out.

(U)The decorrelation time is defined as the time delay for which the autocorrelation coefficient decreases to a value of 1/e. Tables A5 to A8 show the results for the entire 9¼ day sample for averaging times of 4 hours, 1 hour and 10 minutes. From the tables it is apparent that 4 hours of averaging is too long, and 1 hour averaging does not provide adequate resolution. Based on the 10 minute averages, there is a weak trend towards a decrease in the decorrelation time with decreasing bandwidth. For each hydrophone the decorrelation time is significantly higher at 50 Hz than at 100 Hz. The decorrelation time is substantially lower for the suspended hydrophone than for the bottom hydrophone, except for the 0.2 Hz bandwidth at a center frequency of 50 Hz. For all of the data the decorrelation time ranged from 1 hour to more than 6 hours.

(U)To investigate how the decorrelation time depends upon sample length the 0.2 Hz bandwidth data for 10 minutes of averaging time was analyzed in 4 day groups, days 2 to 5 and days 6 to 9, and for each of the 9 days. The analysis was repeated for 1 minute averaging time to further examine averaging time dependence. The results are shown in Tables A10, A12, A14 and A16.

(U)For 10 minute averaging time the results for the 4 day samples were significantly different than for the 9¼ day sample, as is apparent from Table 1. For example, for the bottom hydrophone at 100 Hz with a 0.2 Hz bandwidth the decorrelation time for the 9¼ day sample was 140 minutes; for days 2 to 5 it was 90 minutes, and for days 6 to 9 it was 250 minutes. The suspended and bottom hydrophones do not display systematic results. The decorrelation times for the suspended hydrophone was 120 minutes on days 2 to 5,

TABLE 1

Comparison of Selected Decorrelation Times for the 0.2 Hz Bandwidth Utilizing 10 minute Averaging Time.

		Data Sample Period (days)				
Hydrophone	Frequency	1-9	2-5	6-9	5	7
Bottom	100	140	90	250	40	280
Suspended	100	80	120	40	60	20
Bottom	50	220	170	240	160	220
Suspended	50	380	170	490	120	90

and 40 minutes on days 6 to 9, the reverse of the order for the bottom hydrophone. By contrast, at a center frequency of 50 Hz they were both lower on days 2 to 5 than on days 6 to 9.

(U)On a daily basis the results for 10 minutes of averaging time showed wide variation. The total data set varied from 20 minutes to about 5 hours. The variation between adjacent days can be quite large. For example, from Table (A9) for the suspended hydrophone at a center frequency of 100 Hz, the decorrelation times were 30 minutes and 110 minutes on days 8 and 9, respectively. Similar examples can be found in the remaining tables.

(U)For 1 minute averaging, the decorrelation times were significantly lower, and showed a larger fluctuation. For the 4 day groupings the decorrelation times for the total data set ranged from 7 minutes to 172 minutes. For the daily decorrelation time this trend was further accentuated, with a total range of data from 1 minute to 246 minutes. There is a marked difference, by an order of magnitude, between the suspended and bottom hydrophone at 100 Hz. For the suspended hydrophone the decorrelation time ranged from 1 to 36 minutes with a mean value of about 9 minutes, for the bottom hydrophone the range was 2 to 246 minutes with a mean value of 85 minutes. At 50 Hz the mean values for the suspended and bottom hydrophone were 22 minutes and 76 minutes, respectively.

(U)Tables A17 to A24 provide a comparison of 10 minute and 1 minute averaging times for all 4 bandwidths on days 5 and 7. Of the 16 data sets, 10 sets show decreasing decorrelation time with decreasing bandwidth; 4 sets show increasing decorrelation time with decreasing bandwidth; and 2 sets are erratic. The trend towards decreasing decorrelation time with decreasing bandwidth is more strongly established for 1 minute averaging times, with 6 of the 8 sets displaying this characteristic and the remaining 2 erratic.

CONCLUSIONS AND DISCUSSION

(U)The results described in the previous chapter are based on a relatively limited data sample. The discussion which follows is limited to these results as an indicator of more general conclusions which remain to be confirmed. Our discussion will therefore be qualitative and will not employ any particular set of numbers generated in this study, except as necessary to clarify a particular concept.

(C)As indicated earlier in this report, two primary goals of the study are to determine whether noise statistics are consistent with the usual assumptions made when employing fluctuations to determine cumulative detection probability for passive surveillance systems, and to determine whether there are any special requirements in gathering and processing noise data. We will discuss these separately. For cumulative detection probability the discussion is further limited to the use of an omni-directional system, and the noise component of the total fluctuation in signal to noise ratio.

Cumulative Detection Probability

(C)To simplify the discussion we make the following a priori statements:

1. The larger the standard deviation of noise fluctuations the higher the cumulative detection probability.
2. The lower the decorrelation time of noise fluctuations the higher the cumulative detection probability.

(C)The following general observations are made:

1. The noise statistics are different for a bottom and a suspended hydrophone.
2. The noise statistics are different for different frequencies at the same hydrophone.

(C)For large bandwidth time products* the noise distribution is skewed in the direction of high noise levels. If a normal distribution is assumed for ease of computation, it should be truncated at 2 σ on the low noise side. If truncation is not employed the results will be overly optimistic.

(C)The decorrelation time for large bandwidth time products ranges from about 1/2 hour to 5 hours. If the long term decorrelation time is used to compute the cumulative detection probability the true variability of this term is obscured. For example, assume one computes the area coverage for 24 hour 95% cumulative detection probability for a bottom hydrophone at 100 Hz with a bandwidth of 0.2 Hz and an averaging time of 10 minutes using a decorrelation time of 140 minutes (see Table A5). On a daily basis the cumulative detection probability in the same area will be greater on days 2,3,4 and 5; lower on days 6,7 and 8; and 95% on days 1 and 9 (see Table A11). On days 2,3,4 and 5 the cumulative detection probability will be increased by only a few percentile; in contrast on days 6,7 and 8 the decrease can be substantial. Thus, the average is likely to be below 95%. For a fixed cumulative detection probability the coverage area will be increased on those days when the decorrelation time is reduced. Thus, another way to view this result is that because of daily variation in the decorrelation time the opportunity for "glimpses" of the target will be greater on some days and less on others, when all other conditions remain the same. A more realistic quantitative description could be obtained by computing the probability (p) that the 24 hour cumulative detection probability for a predetermined area exceeds a value (P). A family of curves for different values of the area (A) would provide a more complete description of expectations for an arbitrarily selected day.

*Although the bandwidth and the averaging time have been studied as independent quantities, their product is used in this discussion since the data indicate a broad relationship between the product and the noise statistics. This should not be construed to imply that the statistics are independent of the values of the individual parameters.

(C)For low values of the bandwidth time product the situation is considerably altered. A normal distribution of the noise level is now appropriate, and the standard deviation is increased. The prior comments concerning the decorrelation time also apply to this case. However, the decorrelation time is much shorter; and consecutive independent look intervals will be frequently achieved. If all other system parameters remain the same a reduction in the averaging time reduces the processing gain, thereby reducing detection capabilities, but the increased fluctuation in the noise and the decreased decorrelation time increases the cumulative detection probability. While these effects are balancing, it is difficult to determine how the overall capability will vary with averaging time. For a predetermined bandwidth there may be an optimum range of averaging time for which the detection capability is maximized, but this possibility is not pursued in this report.

(C)Current advanced processing concepts for passive surveillance systems include consideration of a reduction in bandwidth to the order of 0.01 Hz and lower while retaining an averaging time of about 10 to 20 minutes. The bandwidth time product would range from a high of 12 down to unity. It is noted that a 0.2 Hz bandwidth with an averaging time of 1 minute corresponds to a product of 12; and for the 10 second averaging time a product of 2.

(C)It is not at all certain that the results presented in this report can be directly applied to these much narrower bandwidths. We would expect the noise level distribution to be normal and to be independent for consecutive look intervals, but this would have to be confirmed experimentally.

(C)A number of conclusions can be reached relative to gathering and processing basic noise data. We assume that the data is intended to be useful for all low frequency

passive surveillance systems, but will restrict our attention to the statistics of omni-directional noise. If periodic data sampling rather than continuous measurement is employed, the sampling time should be equal to the longest averaging time employed by surveillance systems. This is particularly important for narrow band systems, but can be relaxed if interest is restricted to large values of the bandwidth time constant. Selection of the sampling interval is considerably more difficult. For low values of the bandwidth time product the decorrelation time cannot be determined unless continuous measurements are made. For large values of the bandwidth time product it may be possible to determine the decorrelation time if the sampling interval is short enough. For both continuous and sampled measurements, data processing, reduction and reporting, should follow along the lines of those reported herein. However, the processing need not be as extensive for large bandwidth time products.

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
Unavailable	Brancart, C. P.	TRANSMISSION REPORT, VIBROSEIS CW ACOUSTIC SOURCE, CHURCH ANCHOR EXERCISE, AUGUST AND SEPTEMBER 1973	B-K Dynamics, Inc.	730101	AD0528904	U
Unavailable	Daubin, S. C., et al.	LONG RANGE ACOUSTIC PROPAGATION PROJECT. BLAKE TEST SYNOPSIS REPORT	University of Miami, Rosenstiel School of Marine and Atmospheric Science	730101	AD0768995	U
NUSC TR NO. 4457	King, P. C., et al.	MOORED ACOUSTIC BUOY SYSTEM (MABS): SPECIFICATIONS AND DEPLOYMENTS	Naval Underwater Systems Center	730105	AD0756181; ND	U
MC-012	Unavailable	CHURCH GABBRO SYNOPSIS REPORT (U)	Maury Center for Ocean Science	730210	ND	U
Unavailable	Hecht, R. J., et al.	STATISTICAL ANALYSIS OF OCEAN NOISE	Underwater Systems, Inc.	730220	AD0526024	U
Raff rept 73-2	Bowen, J. I., et al.	EASTLANT SHIPPING DENSITIES	Raff Associates, Inc.	730227	ND AD~~X~~4627	U
Unavailable	Sander, E. L.	SHIPPING SURVEILLANCE DATA FOR CHURCH GABBRO	Raff Associates, Inc.	730315	AD0765360	U
Unavailable	Wagstaff, R. A.	RANDI: RESEARCH AMBIENT NOISE DIRECTIONALITY MODEL	Naval Undersea Center	730401	AD0760692	U
Unavailable	Van Wyckhouse, R. J.	SYNTHETIC BATHYMETRIC PROFILING SYSTEM (SYNBAPS)	Naval Oceanographic Office	730501	AD0762070	U
MCPLAN012	Unavailable	SQUARE DEAL EXERCISE PLAN (U)	Maury Center for Ocean Science	730501	NS; ND	U
Unavailable	Marshall, S. W.	AMBIENT NOISE AND SIGNAL-TO-NOISE PROFILES IN IOMEDEX	Naval Research Laboratory	730601	AD0527037	U
Unavailable	Daubin, S. C.	CHURCH GABBRO TECHNICAL NOTE: SYSTEMS DESCRIPTION AND PERFORMANCE	University of Miami, Rosenstiel School of Marine and Atmospheric Science	730601	AD0763460	U
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Unavailable	Koenigs, P. D., et al.	ANALYSIS OF PROPAGATION LOSS AND SIGNAL-TO-NOISE RATIOS FROM IOMEDEX	Naval Underwater Systems Center	730615	AD0526552	U
NUSC TR 4417	Perrone, A. J.	INFRASONIC AND LOW-FREQUENCY AMBIENT-NOISE MEASUREMENTS OFF NEWFOUNDLAND	Naval Underwater Systems Center	730619	~~ND~~ AD 913668	U
USRD Cal. Report No. 3576	Unavailable	CALIBRATION OF FLIP-CHURCH ANCHOR TRANSDUCERS SERIALS 15 AND 19	Naval Research Laboratory	730716	ND	U